EVALUATION OF REPEATED REMOVAL OF MAMMALIAN PREDATORS ON WATERFOWL NEST SUCCESS AND DENSITY

A Thesis

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ABSTRACT

Low levels of nest success in the prairie pothole region are mainly attributed to changes in predator community and abundance. Removal of predators from large sites (≥ 4144 ha) has been an effective strategy for increasing nest success; however, trapping small sites (< 301 ha) is considered ineffective. I examined the effects of removing predators from 10, 259 ha sites in northeastern North Dakota during 2001-2002. Overall nest success for both years was greater on trapped sites (53.4%) than non-trapped sites (28.7%). Furthermore, daily survival rate was greater on removal sites, and was positively correlated with total predators removed. Differences in nest density were apparent between treatments with an increased nest density on trapped sites, however year had no effect. Pair densities did not differ between treatments, but a 2-fold increase for both trapped and non-trapped sites was found in spring 2002. Cost to produce one fledged duckling, combining all species ranged from $16-20. Overall, the results of this study indicate that repeated removal of predators on small sites is an effective strategy for increasing waterfowl production; however, feasibility will ultimately depend on the user group, budget limitations, landowner objectives, and public acceptance.

INTRODUCTION

The Prairie Pothole Region (PPR) is the primary breeding grounds for waterfowl in North America (Bellrose 1980). Since European settlement, several changes have occurred, with most of these changes negatively affecting waterfowl production in the PPR. Modern agricultural practices have resulted in a loss of breeding habitat through drainage of natural wetlands (Cowardin et al. 1983, Klett et al. 1988), creation of fragmented habitats, and change in predator composition and density (Stoudt 1971, Schranck 1972, Klett et al. 1988, Garrettson et al. 1996).

Nest success is one of the most important factors influencing waterfowl production (Cowardin and Johnson 1979, Klett et al. 1988). Several studies have suggested that various regions in the PPR are not producing sustainable populations of dabbling ducks (Cowardin et al. 1985, Klett et al. 1988, Greenwood et al. 1995). Although habitat loss and fragmentation lower nest success, the primary cause of nest failure is predation by mammals on females and their eggs (Klett et al. 1988, Johnson et al. 1989, Greenwood et al. 1995). Primary mammalian nest predators include the red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*) and striped skunk (*Mephitis mephitis;* Sovada et al. 1995).

Most management techniques to increase nest success focus on creating safe nesting sites for females by decreasing nest predation. Methods include planting dense nesting cover, creating artificial islands (Lokemoen et al. 1982), providing nesting structures, and predator exclosure fences. Habitat management is a common technique, but alone only moderately increases nest success (Clark and Nudds 1991). Nesting islands and predator fences are effective, but are costly to construct and maintain (Greenwood et al. 1990, Lokemoen and Woodward 1993), making them impractical. Similarly, elevated nesting structures substantially decrease nest predation; however, these typically only benefit mallards (Anas platyrhynchos; Bishop and Barrat 1970).

An alternative strategy to increase nest success is to reduce the abundance of nest predators. Early predator management studies found nest success increased considerably when compared to sites without removal (Balser et al. 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980). Historically, removal techniques varied, with the use of poisons, such as strychnine, as the most common method of removal. Control of predators with poisons was highly effective, but is non-selective and no longer a legal method of removal. Today, trapping is the primary method of predator removal, but studies using this technique have reported contradicting results. A current question regarding removal is at what scale to manage. Removing predators from large sites (≥ 4144 ha) is an effective method for increasing nest success (Balser et al. 1968, Duebbert and Kantrud 1974, Garrettson et al. 1996, Garrettson et al. 2001). On large sites (4144 ha), Garrettson and Rohwer (2001) found a two-fold increase in nest success on trapped versus non-trapped areas, whereas a study examining predator removal on small sites (61-301 ha) was ineffective at increasing nest success above the 15-20 % level necessary to sustain stable populations (Sargeant et al. 1995).

I examined the effectiveness and feasibility of repeated removal of medium-sized mammalian predators on small (259 ha) grassland sites. A study by Sargeant et al. (1995) speculated that reduced trapper work schedules and limited methods of removal lowered trapping efficiency. Therefore all legal methods of removal and a more flexible trapper work schedule were incorporated into my study. I examined pair density, nest density, and nest success, as they are all determinants of waterfowl productivity. A second objective for my study was to examine the cost effectiveness of predator removal. To do this I calculated cost of production for one duckling. Secondarily, I sought to determine if an optimal time period exists for removing predators to benefit waterfowl production.

STUDY AREA

This study was conducted during 2001 and 2002 on 20, 259 ha-sites in Cavalier, Ramsey, and Towner Counties, North Dakota. Gently rolling hills interspersed with seasonal and semipermanent wetlands, as well as permanent lakes characterize this region. The landscape was dominated by cereal grain agriculture, with most non-agricultural lands grouped as Waterfowl Production Areas (WPAs) or enrolled in the Conservation Reserve Program (CRP). The predator community was diverse; including Franklin's ground squirrels (*Spermophilus franklinii*), striped skunk, raccoon, red fox, coyotes (*Canis latrans*), mink (*Mustella vison*) and American crow (*Corvus brachyrhynchos*). However, species of interest include the red fox, coyote, raccoon, striped skunk, and mink (Sargeant et al. 1993, Sovada et al. 1995), as they all prey on nesting waterfowl and their ducklings.

National Wetland inventory maps and aerial photos were used to select sites with > 25% grassland and an abundance of semi-permanent wetlands. For this study, sites were a combination of WPA and CRP lands. Sites were designated a treatment of trapped or non-trapped, and were paired for nest searching purposes based on similar characteristics (proportion of grassland and wetland density). Sites were located ≥ 2 miles apart to reduce the effects of predator removal affecting other sites.

METHODS

Predator Removal

One professional trapper was hired to remove target species, including raccoon, red fox, skunk, and mink on the 10 trapped sites. The same sites were trapped in 2001 and 2002. Methods of removal included padded foothold traps, baited box traps, body-gripping traps, snares, and shooting. Removal began 12 March – 30 April and continued until 1 July – 15 July for 2001 and 2002, respectively. The trapper recorded number and type of traps set, species caught, and trap type of capture. The trapper was paid $19,200/year, plus a bonus of $1000 if apparent nest success was > 50%, which occurred in both years. For trapped sites, I used a simple linear regression to test for a relationship between daily survival rate (DSR) for nests and total number of predators removed.

This research was approved by the Louisiana State University Animal Care and Use Committee (A01-03). Predator removal and nest searching/monitoring for 2001-2002 on Waterfowl Production Areas was conducted under U.S. Fish and Wildlife Service special use permits DLWMD-01-015 and DLWMD-02-002, respectively.

Breeding Pair Counts

Breeding pair counts were conducted on 20 randomly selected quarter sections (65 ha) on each site from late-April to early-May during springs 2001-2002. All sites were counted 3 times to ensure all species were sampled sufficiently. Observers recorded wind speed, date, temperature, species, and pairing status. To avoid duplications in counts, species, gender, time, and flight direction of flushed ducks was recorded. Early nesting species included mallard and northern pintail (*A. acuta*), whereas blue-winged teal (*A. discors*), northern shoveler (*A. clypeata*), and gadwall (*A. strepera*) were classified as mid-to-late nesting species. Breeding pairs were classified as a pair (male and female in close association) or an indicated pair (Kantrud and Stewart 1977). An indicated pair was defined as a: (1) lone drake with no visible associated female; (2) mixed flock of 1 female and several males; (3) flock of drakes (maximum 4, each assumed to be a pair).

Breeding pair density on trapped and non-trapped sites was compared using an analysis of covariance (ANCOVA, Proc Mixed, SAS Institute Inc 1999) with the interaction between site and treatment as the random effect, and pond density as the covariate. In calculating breeding pair density, pond area was used instead of shoreline length, since Fischer (1994) found pond number and pond area were correlated with shoreline length (r=0.442) and area (r=0.644), and large variations between shoreline lengths were exhibited in this study.

Nest Searches

I searched for nests 3 times on each site from late April until early July to ensure adequate sample sizes of all ducks. Sites searched varied in size from 65-259 ha of actual nesting habitat. Nests were located using a 2-person crew dragging a 50m chain between 2 all-terrain vehicles (Klett et al. 1986). Nest searching occurred between 0800 and 1400 to increase the chance of finding a female on her nest (Gloutney et al. 1993). Nests were marked with white lathe 15m north of the nest with an orange 3mm welding rod placed at the nest. Upon nest discovery, time, date, species, clutch size, and incubation stage (Weller 1956) were recorded. A GPS coordinate was recorded for each nest to ease in relocation. Nests were re-visited every 7-10 days to determine nest fate (Klett et al. 1986). A nest was categorized abandoned, destroyed or successful if one egg hatched.

Nest Success

To estimate nest success, total exposure days were converted to DSR for nests using the Mayfield method (Mayfield 1961) as modified by Johnson (1979). Nests were excluded from the analysis if they were abandoned due to investigator activity, included only infertile eggs, or resulted in no fate determination (Greenwood et al. 1995). To test for a difference in DSR between trapped and non-trapped sites, an analysis of variance (ANOVA, Proc Mixed, SAS Institute Inc. 1999) weighted by exposure days (Greenwood et al. 1995) with the interaction between site and treatment as the random effect was used. To simplify calculations, nest success = $(DSR)^I$, where I=35. For each nest success estimate, 95 % confidence intervals were calculated. To test for a difference in species composition of nests between trapped and non-trapped sites a multivariate analysis of variance (MANOVA, Proc Glm, SAS Institute Inc. 1999) was used. Species included in this analysis were mallards, northern pintails, gadwall, blue-winged teal, and northern shoveler.

Nest Density

Mean nest density was calculated using all nests found per site. To test for a difference in nest density between trapped and non-trapped sites between years, an analysis of variance was used (ANOVA, Proc Mixed, SAS Institute Inc. 1999).

Cost Effectiveness

The cost of production model, $Y = [(S_i*X*H_s)/(T)]$, included Y = cost of production, S_i = survival, X = number of successful nests, H_s = number of hatched ducklings per nest, and T = cost of trapping. Cost effectiveness of predator management was calculated for duckling class I-III. Survival estimates used for class I, II, and III were 0.4664, 0.4145, and 0.3951, respectively. The survival estimate for class III was the product of class I, II, and III survival probabilities, whereas class II was the product of class I and II survival probabilities (Orthmeyer and Ball 1990). The number of successful nests was the product of the combined total number of successful nests from both treatments and the difference in nest success between treatments. Average number of ducklings per nest was calculated by summing total ducklings of all species produced for trapped and non-trapped sites per year and dividing this value by the combined total number of successful nests for trapped and non-trapped sites per year. Average number of hatched ducklings for 2001 and 2002 was 9.4 and 7.1 ducklings per nest, respectively. Trapping costs only included trapper salary ($20,200).

RESULTS

Predator Removal

A total of 690 predators were removed during the study. Of these, striped skunk, raccoon, and mink were most commonly captured (Table 1), with badgers, red fox, coyotes, and Franklin's ground squirrel accounting for the remainder. No optimal time period for removing predators was apparent from the temporal distribution of captures for 2001-2002 (Figure 1). DSR was positively correlated with total number of predators removed from trapped sites ($R^2 = 0.476$, $P = 0.002$), as well as with raccoons ($R^2 = 0.235$, $P = 0.068$) and skunks ($R^2 = 0.254$, $P = 0.053$).

Breeding Pair Counts

Blue-winged teal pairs were the most abundant species in 2001, with twice as many pairs as other species; however, mallards and gadwall were more prevalent in 2002 (Table 2). Densities of breeding pairs on all sites increased 2-fold from 2001 to 2002, with year ($F_{1, 14} = 14.26$, $P = 0.002$) effects; however there were no treatment ($F_{1, 18} = 0.60$, $P = 0.450$), or year-treatment ($F_{1, 14} = 0.34$, $P = 0.568$) effects.

Nest Success

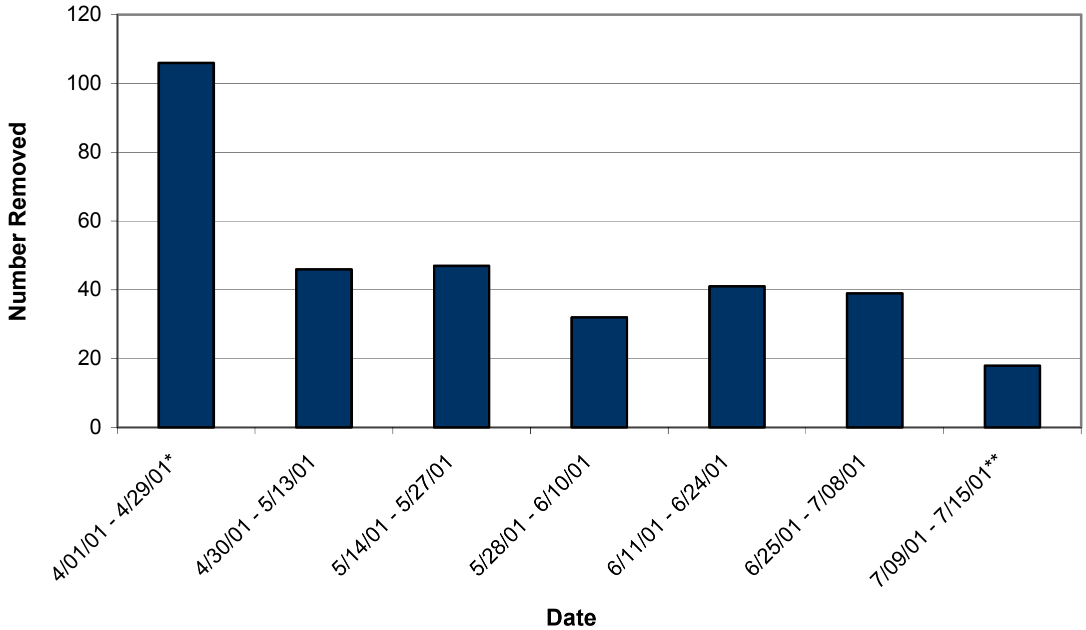
Overall, 4389 nests were located, with 4240 nests (97%) appropriate for analysis. Mallards comprised 39% of all nests found, followed by blue-winged teal (27%), gadwall (18%), northern shoveler (8%), and northern pintail (7%). American wigeon (*A. americana*), and green-winged teal (*A. crecca*) comprised < 1%.

Daily survival rate was greater on trapped sites (0.982 ± 0.002) than non-trapped sites (0.965 ± 0.003) for years combined ($F_{1, 18} = 21.92$, $P < 0.001$); however, no year ($F_{1, 18} = 0.93$, $P = 0.349$) or year-treatment ($F_{1, 18} = 0.26$, $P = 0.619$) effects were found. Mean Mayfield nest

Table 1. Number and species of mammalian predators removed from 10, 259 ha trapped sites in Cavalier, Ramsey, and Towner Counties, North Dakota 2001-2002.

		Raccoon				Skunk				Mink				
Year	Site	March[a]	Apri	May	June[b]	March[a]	April	May	June	March[a]	April	May	June[b]	Total[c]
2001	19 Banner		0	1	4		3	5	12		2	2	2	36
	26 Banner		0	4	3		5	2	4		4	5	0	33
	28 Klingstrup		4	4	4		5	3	4		3	2	0	24
	13 Northfield		2	2	4		8	7	4		0	0	0	32
	19 Royal		2	1	2		6	2	4		2	1	1	32
	35 Royal		5	8	9		5	5	5		3	2	1	45
	3,9,10 Storlie		5	3	5		6	2	3		2	1	3	37
	7 Twin Hill		2	1	0		6	4	6		3	3	1	29
	33 Twin Hill		2	4	7		7	2	4		2	3	0	32
	27 Victor		2	1	1		10	4	6		4	2	2	35
2002	19 Banner	2	1	4	3	4	0	3	4	2	5	3	1	34
	26 Banner	0	1	1	6	2	6	3	2	0	3	3	2	34
	28 Klingstrup	1	4	2	5	3	7	4	6	0	1	2	0	38
	13 Northfield	2	1	2	2	3	5	4	3	0	4	0	0	27
	19 Royal	0	5	0	1	1	5	7	1	0	7	0	0	30
	35 Royal	3	2	11	4	4	5	13	4	0	5	0	1	56
	3,9,10 Storlie	2	1	0	2	2	3	9	6	1	3	0	1	32
	7 Twin Hill	0	2	4	2	5	10	7	4	0	4	0	1	50
	33 Twin Hill	0	0	0	1	2	11	9	1	0	3	2	0	29
	27 Victor	1	1	2	2	4	6	3	1	0	1	0	3	25
	Grand Total	11	42	55	67	30	119	99	84	3	61	31	19	690

[a] Trapping in March for 2002 only; [b] Includes June and first 2 weeks in July for 2001, and only June for 2002; [c] Also includes red fox, badgers, weasels, and Franklin's ground squirrels.



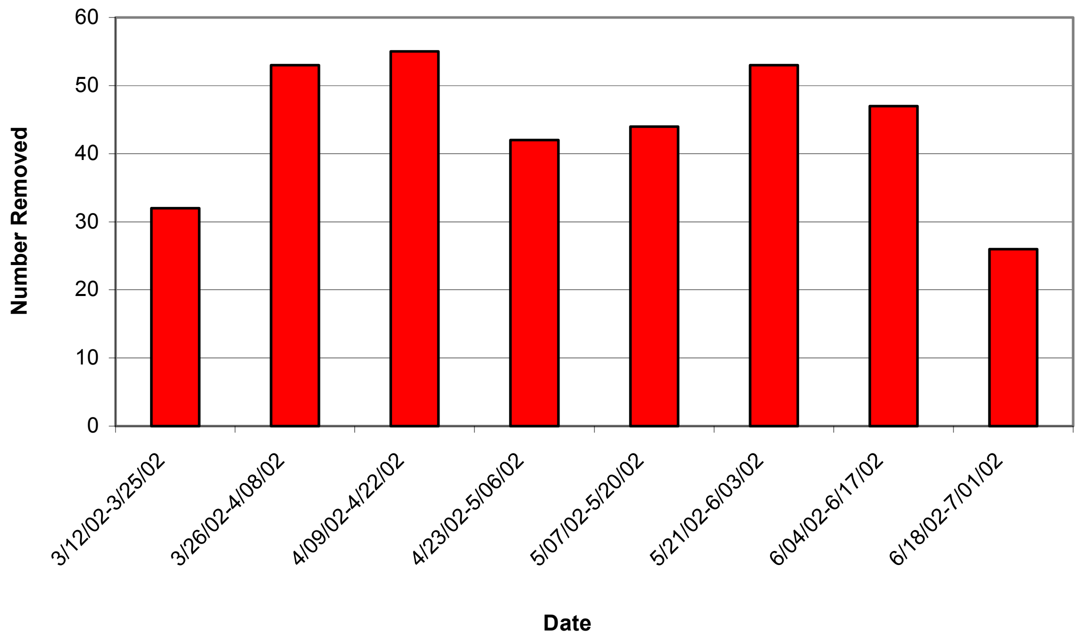


Figure 1. Temporal distribution of predators removed for 2-week intervals on trapped sites (259 ha) in north-central North Dakota for 2001 (top figure) and 2002 (bottom figure). * - 4-week interval; ** - 1-week interval.

Table 2. Mean number of breeding pairs ± SE for dabbling ducks on trapped and non-trapped sites in north-central North Dakota 2001-2002.

	2001				2002			
	Trapped[a]		Non-trapped[b]		Trapped[a]		Non-trapped[b]	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Blue-winged Teal	59.0	20.5	56.5	20.0	28.4	13.3	21.8	17.5
Gadwall	24.5	13.9	18.7	18.6	35.4	31.0	28.6	22.2
Mallard	27.9	14.0	29.1	19.1	46.6	18.9	31.1	14.7
Northern Pintail	9.6	6.3	6.0	3.7	14.2	13.8	6.3	5.8
Northern Shoveler	25.6	12.5	21.0	9.5	25.3	18.2	18.5	15.7
Green-winged Teal	0.3	0.5	0.8	1.2	5.0	5.2	1.7	2.7
American Wigeon	0.9	1.4	0.4	0.7	0.8	1.7	1.5	1.8

[a] n=10
[b] n=10

success on trapped sites (53.4%) was nearly double that of non-trapped sites (28.7%) for both years combined (Table 3). Reasons for abandonment included investigator influence, flooding, and unknown factors.

Nest Density

Trapped sites exhibited higher nest densities than non-trapped sites ($F_{1, 18} = 3.82$, $P = 0.067$), with year-treatment ($F_{1, 18} = 3.08$, $P = 0.096$) effects, however there was no year ($F_{1, 18} = 2.28$, $P = 0.148$) effect. Overall nest density on trapped sites in 2001 and 2002 were 0.28 nests/ha and 0.37 nests/ha, respectively. Furthermore, nest density on non-trapped sites was lower with 0.22 nests/ha and 0.21 nests/ha for 2001 and 2002, respectively.

Cost Effectiveness

Cost of production for any species of dabbling duck for 2001 and 2002 were similar for all duckling classes. Production estimates for class I, II, and, III ducklings for 2001 were $16.77, $18.87, and $19.80, respectively. Cost estimates in 2002 were slightly lower, costing $16.41, $18.46, and $19.37 for class I, II, and III, respectively.

Table 3. Mayfield nest success estimates (95% CI) for upland nesting ducks on trapped and non-trapped sites in north-central North Dakota 2001-2002.

		2001		2002	
Treatment	Site	Success	95% CI	Success	95 % CI
Non-trapped	6 Crocus	34.5	21.8-54.2	12.5	3.8-39.7
	21, 22 Crocus	46.0	32.7-64.6	6.8	3.2-14.3
	24 Virginia	6.4	2.2-17.8	19.7	9.4-40.7
	8 Klingstrup	33.2	20.4-53.7	28.3	18.9-42.2
	35 Northfield	41.5	33.5-51.5	8.3	4.0-16.9
	35, 36 Storlie	31.0	22.0-43.6	48.8	39.9-59.6
	4, 5 Royal	26.4	18.6-37.4	39.2	30.5-50.3
	14, 15 Billings	30.2	20.3-44.5	49.7	37.5-65.7
	29, 30, 31 Moscow	24.4	14.6-40.2	16.1	9.1-28.3
	27, 34 Sievert	29.0	21.0-39.9	17.3	12.8-23.2
	Average	31.3	27.8-35.2	26.0	23.0-28.3
Trapped	27 Victor	71.8	62.0-83.0	76.4	69.6-83.9
	7 Twin Hill	60.2	48.6-74.4	19.0	12.6-28.5
	33 Twin Hill	61.6	48.2-78.7	54.3	40.6-72.5
	28 Klingstrup	55.3	38.2-79.7	73.7	63.5-85.6
	19 Royal	93.2	81.2-107.0	35.5	23.0-54.6
	35 Royal	26.4	18.1-38.4	30.8	22.0-43.1
	13 Northfield	57.3	48.1-68.2	43.5	35.9-52.7
	3, 9, 10 Storlie	57.2	48.5-67.5	48.9	42.2-56.6
	19 Banner	42.7	33.8-53.8	55.9	46.6-66.9
	26 Banner	56.8	49.8-64.9	58.3	51.6-65.7
	Average	54.9	51.4-58.6	51.8	48.8-54.9

DISCUSSION

Nest success in the PPR is steadily declining as a result of high predation rates. Removing predators from large sites ($\geq$ 4144 ha) with poisons and trapping are effective methods to increase nest success (Balser et al. 1968, Duebbert and Kantrud 1974, Garrettson et al. 2001); however, a study examining predator removal on small sites (62-301 ha) using trapping was costly and ineffective at increasing nest success above levels to sustain stable populations (Sargeant et al. 1995). Overall, I found trapping small sites to be an effective management strategy to increase nest success.

Nest success is the primary variable indicative of waterfowl productivity. Nest success on trapped sites was double that of sites without predator removal, which is an interesting result since a well-replicated study on small blocks (61-301 ha) of grassland was ineffective at increasing nest success on trapped blocks above 15% (Sargeant et al. 1995). Predator removal may have been more effective for my study because of a more flexible trapper work schedule, increased financial incentives for the trapper, increased removal techniques (use of snares) not implemented in the Sargeant et al. (1995) study, and large sample sizes of nesting females. Furthermore, Sargeant et al. (1995) found DSR was not related to the number of predators removed. However, in my study, a positive correlation existed between DSR and the number of predators removed, indicating the importance of meso-carnivores in determining the fate of duck nests.

Although nest success was substantially increased by predator removal, nest success on non-trapped sites (28.7%) was above levels necessary to sustain stable populations of waterfowl (Cowardin et al. 1985, Klett et al. 1988, Greenwood et al. 1995). Lack of red foxes and good habitat conditions among sites were potentially causal. Previous studies found red fox predation to be an important factor limiting nest success of dabbling ducks in the prairies, accounting for 27% of nest failures (Duebbert and Lokemoen 1976, Sargeant et al. 1984, Sovada et al. 1995). The prevalence of sarcoptic mange in this region for the past few years has contributed to reduced red fox populations (Delta Waterfowl, unpublished data). Additionally, all sites had > 25% grassland, which may have provided safe nesting sites for females.

Annual breeding pair numbers are an important variable considered when calculating yearly recruitment rates of breeding waterfowl (Dzubin 1969, Cowardin and Blohm 1992). I found pair density increased in 2002, but did not differ between treatments, suggesting that predator removal had no effect on pair density. Nest density may be a better indicator of recruitment as it was higher on trapped sites in 2002. In years of drought, waterfowl will bypass less productive habitat in search of areas with optimal water conditions. Two-fold increases in pair densities on all sites may be attributed to drought conditions in the PPR of spring 2002. Northeastern North Dakota was one of the few regions in the prairies retaining adequate amounts of water to produce fair/good nesting conditions (Ducks Unlimited Magazine 2002). Ducks are strongly influenced by pond availability when searching for a breeding area (Johnson and Grier 1988). As a result of poor water conditions, ducks returning to the breeding grounds may not have been as selective, and chose sites based on the presence of water rather than areas of success in previous years. Furthermore, pair densities may not have differed between treatments because of habitat similarities between trapped and non-trapped sites.

A second factor influencing pair densities is the homing of successful females. Increased survival of females one season leads to higher female philopatry the following year (Lokemoen et al. 1990, Anderson et al. 1992). Although mallards and gadwall exhibit greater rates of homing relative to other species, blue-winged teal pairs were abundant in spring 2001, which may be a result of high seasonal and temporary wetland densities. Blue-winged teal prefer these ponds to larger permanent ponds. Drought conditions in spring 2002 resulted in most wetlands being semi-permanent and permanent.

Although effective at increasing nest success, cost effectiveness and public acceptance will likely determine the feasibility of predator management at larger scales. To produce one fledged duckling it cost $16-20. Few studies have calculated the cost of dabbling duck production from predator management. Balser et al. (1968) reported it cost $0.31 to produce one duckling, however this study used poisons and is dated. Therefore, I compared cost effectiveness of dabbling duck production with trapping to wood duck production from nest box programs. In regions where natural cavities are lacking, placement of wood duck boxes is an acceptable management strategy to increase wood duck production. In Wisconsin, Soulliere (1986) determined the actual cost for producing a flighted juvenile wood duck ranged from $25-$120. Therefore, predator management on sites similar to those used in my study is similar in cost to the lowest cost estimate to build and install wood duck boxes based on finding of Soulliere (1986). Whether cost estimates of $16-20 are feasible will ultimately rely on management objectives, landowner goals, and budgetary limitations.

Historically, public perceptions of predator removal were disapproving because of suspected negative impacts on human activities, such as interference with personal trapping and increased crop damage (Duda and Young 1998). Landowners who disapproved of trapping in my study voiced similar concerns, as well as conflicts with the government, and fear for their pet's safety. Historically, large predators such as wolves (*Canis lupus*) were persecuted to near extinction in most regions. With the re-introduction of wolves in the early 1980's, public attitudes towards large carnivores became increasingly positive. Kellert (1985*a*) and Hook and

Robinson (1982) found anti-predator attitudes decreased with urbanization and increased education. Today, large carnivores are regarded as a symbol of wilderness and no longer persecuted, but protected. However, Messmer et al. (1999) found a greater percentage of the public favored predator removal if it improved avian recruitment, especially if the predators were less appealing meso-carnivores (raccoon and skunk). Because changes in public opinion regarding predator removal vary depending on species, and also may change with respect to location, a logical direction for future research would be to quantify public attitudes towards predator removal in the region of study.

RECOMMENDATIONS

Predator management is an effective method to increase nest success; however, the feasibility is dependent upon the user because of elevated production costs. Costs may be reduced by: (1) applying predator removal to WPAs where nest success is lowered because of high predation rates; (2) remove only one predator species (red fox, raccoons, or skunks) where nest predation by other species is low; or (3) discourage the removal of coyotes.

To protect and increase grassland cover in the prairies, the U.S. Fish and Wildlife Service created WPAs to benefit nesting waterfowl (Cowardin et al. 1995); however, Klett et al. (1988) and Sargeant et al. (1995) found low levels of nest success on some WPAs. Although the primary function of CRP land was to increase commodity prices by lowering production, a secondary benefit was that it provided habitat for wildlife. With the abundance of grassland cover and wetlands, this habitat has become important nesting habitat for waterfowl. Furthermore, Reynolds et al. (2001) found CRP greatly enhanced nest success when compared to non-CRP land. Although habitat management is beneficial to waterfowl production, recruitment may be enhanced by combining habitat management with predator removal, especially on sites of high predation. By increasing rates of production, costs of predator management may be reduced.

Targeting one predator species is difficult; however, Greenwood (1986) found nest success increased marginally (10%) in eastern Montana where striped skunks were the only predator removed. Furthermore, this strategy may be socially more acceptable than removing all predator species. In California, Jaeger et al. (2001) found coyote control to protect sheep herds was socially more acceptable when alpha male and female coyotes were selectively targeted.

A third alternative is to discourage trapping of coyotes. Although coyotes prey on nesting waterfowl, they are not as detrimental to waterfowl populations as red foxes (Klett et al. 1988, Sovada et al. 1995). Red foxes are an introduced predator in the prairies, which prey heavily on females and their nests (Sargeant et al. 1984, Sovada et al. 1995). Coyotes are known to suppress red fox populations, and in some instances have caused local extinction of red foxes (Dekker 1983, Voigt and Earle 1983). Furthermore, increases in nest success were observed in regions where coyotes suppressed red fox populations (Klett et al. 1988, Sovada et al. 1995). Further research is required to determine if coyote management would be an effective alternative strategy to benefit nesting waterfowl.

Cost effectiveness also may be influenced by brood and duckling survival. A study by Pearse (2002) in south-central Saskatchewan found predator removal increased 30-day mallard duckling survival by 22% on trapped sites compared to non-trapped sites. Therefore, if this same trend occurred on my trapped sites, current cost estimates for this study would be slightly inflated. A logical direction for future predator management research would be to determine effects of trapping on brood and duckling survival, in addition to nest success prior to evaluating cost effectiveness.

The long-term effectiveness of predator removal is unknown. Carnivore space use patterns and reproductive rates allow populations to rapidly respond to removal of conspecifics. For instance, Benson et al. (2003) found that death of resident bobcats resulted in immediate occupancy of vacated home ranges by transients in Mississippi. Gray fox pairs disturbed by death of a mate were reported to maintain home ranges in the absence of their mate, even successfully rearing kits along (Chamberlain and Leopold 2002*a*). Knowlton (1972) found that under intensive control, coyote populations responded by essentially doubling litter sizes.

Whether mesocarnivores, such as skunks, raccoons, and red foxes on the northern prairies respond similarly is unclear. However, these species have strong intrinsic and/or physiological regulatory mechanisms similar to bobcats and gray foxes, such as territoriality among solitary or grouped raccoons (Fritzell 1978, Gehrt and Fritzell 1997, Chamberlain and Leopold 2002*b*) and social dominance and young-rearing capabilities in red foxes (Voigt 1987). Therefore, predator removal may ultimately have a low net positive effect when trapping ceases, as mesocarnivores subsequently respond to the absence of conspecifics and improved competition for resources, and would encounter a greater abundance of nesting waterfowl as a result of increased nest density following removal. As a result, measures of waterfowl productivity may be negatively affected following the cessation of predator removal, thereby negating positive effects in prior years. Future research should examine long-term effects of predator removal on waterfowl production.

Most predator management studies for waterfowl concentrate on the direct effects of predator removal on nesting ducks. My study examined the effects of repeated removal of meso-carnivores on waterfowl nest success, however other populations of songbirds and rodents also may be influenced indirectly. Dion et al. (1999) found predator removal had no significant effects on success of grassland songbirds in the short term; however, Dion et al. (2000) speculated that predator removal might indirectly affect songbird nest success by altering the foraging behavior of microtenes. Small mammal diversity and abundance also may increase with the removal of duck nest predators. A concurrent small mammal study using the same sites as my research found that rodent densities increased on trapped sites compared to non-trapped sites (Atkins, J., unpublished data). Further research is required to determine effects of meso-carnivore removal on lower trophic levels.

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VITA

Kristen Dawn Chodachek was born on March 27, 1978, in Winnipeg, Manitoba. Growing up in rural south central Manitoba gave Kristen the opportunity to enjoy all the prairies offered. Most of her childhood was spent outdoors playing with her brothers, fishing, camping, and enjoying nature. After graduating from Sanford Collegiate High School in 1996, Kristen decided to further her knowledge of wildlife by attending University. In 2001, she graduated from the University of Manitoba with a Bachelor of Science degree in zoology.

During the summer of 2000, the Delta Waterfowl Foundation employed Kristen as a seasonal field assistant. After spending a summer working with Liz Loos, Andrea Hoover, Dawn Zirrillo, and Dr. Frank Rohwer studying dabbling ducks, she fell in love with the prairies all over again. Although field research is not glamorous and the living conditions are challenging to say the least, Kristen decided research was something she wanted to pursue.

In the spring of 2001, she was accepted in the School of Renewable Natural Resources at Louisiana State University as a master's candidate. Kristen did her research through the Delta Waterfowl and Wetlands Research Station and in 2002 won their Peter W. A. Green Communications Award. The degree of Master of Science in Wildlife Science will be awarded in May 2003.